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structional Design and Training Delivery | Selecting and Implementing Performance Interventions | Measurement and Evaluation

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EDITED BY Kenneth H. Silber and Wellesley R. Foshay

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WHERE KNOWLEDGE BECOMES KNOW-HOW

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14. ABSTRACT

This chapter begins by defining a few key concepts that are critical to understanding the nature of tasks and task analysis. A brief overview of the development of task analysis and the distinction between behavioral task analysis and cognitive task analsis is presented. The general questions that behavioral task analysis helps answer is listed describing the typical stages involved in conducting a behavioral task analysis. Following the general discussion, several cases illustrating specific applications are presented as well as some limitations and pitfalls. Finally, a brief overview of tools that are available to assist in conducting a task analysis is given.

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CHAPTER SIX

Behavioral Task Analysis*

Herbert H. Bell
Dee H. Andrews
Wallace H. Wulfeck II

INTRODUCTION

Behavioral task analysis is a fundamental tool of the human systems professional for a variety of processes. In one form or another, task analysis plays an important role in mission analysis, organizational design, job design, system design, quality improvement, personnel selection, training, and evaluation.

Simply put, task analysis helps us understand what people do when they successfully accomplish their work. Mager (1988) described task analysis as "a collection of techniques used to help make the components of competent performance visible" (p. 29). Behavioral task analysis focuses on the behaviors people perform while doing their jobs. Typically, these behaviors are documented as discrete tasks or procedures individuals must accomplish to successfully perform a job (Jonassen, Hannum, & Tessmer, 1989). For training design, the task analysis process continues to identify conditions, actions, and standards for each task to be trained and each performance to be assessed.

It is impossible to cover all the details of task analysis in a single chapter. Indeed, there are a number of books devoted entirely to task analysis (Annett & Stanton, 2000; Carlisle, 1986; Hackos & Redish, 1998; Jonassen, Hannum, & Tessmer, 1989; Jonassen, Tessmer, & Hannum, 1999; Kirwan & Ainsworth, 1992). Because task analysis covers such a wide range of processes and involves a number of different disciplines, there are a variety of techniques for performing

* *Note:* The opinions expressed in this chapter are those of the authors and do not necessarily represent the official views or policies of the Department of Defense or the Services.

task analyses and a number of different ways to describe the resulting products. This complexity is reflected in the FAA Human Factors Workbench, which lists thirty-one different tools to support task analysis (Federal Aviation Administration, n.d.). Given the scope of task analysis, the large number of tools available for task analysis, and the different theoretical foundations and terms used by practitioners, task analysis may seem overwhelming to a newcomer.

The primary focus of this chapter is on behavioral task analysis for training. This chapter and Chapter Seven in this volume on cognitive task analysis by Villachica and Stone will provide the reader with a working knowledge of task analysis and an understanding of how task analysis helps people have the right tools, knowledge, and skills to perform their work successfully.

The military nurtured many of the task analysis concepts and methods used today in order to design complex systems and train large numbers of people to operate those systems. As a result, many of our examples involve military applications of behavioral task analysis. These same concepts have been adapted and used in a number of different areas such as organizational design and human-computer interaction across both public and private sectors.

This chapter begins by defining a few key concepts that are critical to understanding the nature of tasks and task analysis. Next, we present a brief overview of the development of task analysis and the distinction between behavioral task analysis and cognitive task analysis. Then we list the general questions that behavioral task analysis helps answer and describe the typical stages involved in conducting a behavioral task analysis. Following this general discussion, several cases illustrating specific applications are presented as well as some limitations and pitfalls. Finally, a brief overview of tools that are available to assist in conducting a task analysis is given.

FUNDAMENTAL CONCEPTS

What Is Behavioral Task Analysis?

Task analysis is applicable throughout the life cycle of a system. Meister (1985) identified various areas within the system life cycle where task analysis is especially useful and the types of questions addressed by task analysis. Table 6.1 presents an abbreviated summary of those areas and questions. As illustrated, the information gathered from a particular question is often applicable to several areas. For example, the system designer must provide operators timely and correct displays that cue the need to perform a particular task. Similarly, training developers must ensure that correct relationships between cues and control behaviors are established during training, and both the system designer and the training developer must identify criteria for successful performance.

Table 6.1 System Life Cycle Stages and Relevant Task Analysis Questions

Area of Interest	*Sample Questions*
Design	What tasks need to be performed and how should they be performed?
	What are the consequences of failing to perform a task or performing it inadequately?
	What is the order in which tasks must be performed?
	What information is needed to perform the task?
	What actions must the operator perform to accomplish the task?
	What coordination is required?
	What are the perceptual, cognitive, psychomotor, and physical demands?
	What errors are likely?
Staffing	How many people are required to perform the task?
	What knowledge, skills, abilities, and experience are required to perform the task?
Training	What behaviors underlie each task?
	How difficult or complex is the task?
	What information is necessary to perform the task?
	What are the criteria for successful performance?
	What are the consequences of not performing or inadequately performing a task?
	What is the relationship between various tasks?
	How frequently is the task performed?
Performance Evaluation	What are the criteria for successful performance?
	What are the consequences of poor performance?

Based on Meister, 1985

Tasks are performed to accomplish work for specific purposes under specific conditions. Behavioral task analysis involves collecting, abstracting, organizing, and reporting information about what people do in performing work. There are a number of different ways to collect data about tasks, abstract that data into organized categories, and present that data. Because of these differences, the terminology associated with task analysis varies across practitioners. Table 6.2 lists many of the terms commonly associated with task analysis and provides a brief definition of each term.

Table 6.2 Common Task Analysis Terms

System *acq.*	A composite of equipment, skills, and techniques capable of performing or supporting an operational role, or both. A complete system includes all equipment, related facilities, material, software, services, and personnel required for its operation and support to the degree that it can be a self-sufficient unit in its intended operational environment.
Task analysis *acq.*	A systematic method used to develop a time-oriented description of personnel/equipment/software interactions brought about by an operator, controller, or maintainer in accomplishing a unit of work with a system or item of equipment. It shows the sequential and simultaneous manual and intellectual activities of personnel operating, maintaining or controlling equipment, in addition to sequential operation of the equipment. It is a part of system engineering analysis where system engineering is required. The following taxonomy is used to inventory or analyze tasks, with mission and scenario conditions stated by the procuring activity and the remaining levels dependent on the current phase of system development and purpose (e.g., gross analysis of task analysis of critical tasks) for which the analysis is being conducted.
Mission	What the system is supposed to accomplish, e.g., combat reconnaissance.
Scenario/ conditions	Categories of factors or constraints under which the system will be expected to operate and be maintained, e.g., day/night, all weather, all terrain operation.
Function	A broad category of activity performed by a system, e.g., transportation.
Job	The combination of all human performance required for operation and maintenance of one personnel position in a system, e.g., driver.
Duty	A set of operationally related tasks within a given job, e.g., driving, weapon servicing communicating, target detection, self protection, operator maintenance.
Task	A composite of related activities (perceptions, decisions, and responses) performed for an immediate purpose; written in operator/maintainer language, e.g., change a tire.
Subtask	An activity (perceptions, decisions, and responses) that fulfills a portion of the immediate purpose within the task, e.g., remove lug nuts.
Task element	The smallest logically and reasonably definable unit of behavior required in completing a task or subtask, e.g., apply counterclockwise torque to the lug nuts with a lug wrench.

Department of Defense, 1999, pp. 30–32 in hierarchical order

This chapter uses the generic model and terms shown in Figure 6.1 to provide an organizing structure for the concepts associated with task analysis. This model reflects a synthesis of many theorists and practitioners, most importantly Annett (2004), Meister (1985), and Miller (1953, 1962). Its purpose is to provide a context for understanding behavioral task analysis and a means of describing behavior in a meaningful way.

System. As shown in Figure 6.1, work occurs within a system context to affect or control some specific part of the environment.

Vincente (1999) defines a system as "a set of interrelated elements that share a common . . . [p]urpose" (p. 9). There are four important ideas embedded within this definition.

1. A system exists for a purpose.
2. The system can be decomposed into elements or subsystems.
3. The overall purpose of the system determines the interrelationship of system elements.
4. The system can be viewed hierarchically.

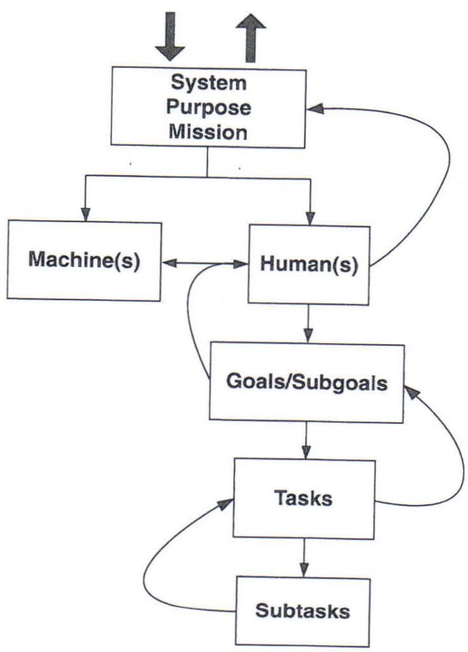

Figure 6.1 Generic Task Domain.

The system perspective allows us to understand the reason for performing a particular task, how it relates to other tasks, and the consequences of various levels of performance. Work is performed as part of a specific system comprised of multiple elements in order to enable the system to achieve its purpose.

A system perspective is necessary to understand tasks because it contextualizes human behavior in terms of purpose, identifies factors that influence the performance of tasks, and describes how specific activities contribute to the successful completion of work (Meister, 1985, 1989). Without the system view, it would be very difficult to do anything other than simply list the sequence of task behaviors. The system perspective provides a means to understand why and how specific tasks contribute to the successful completion of work.

Purpose. As noted above, a system exists to achieve a particular purpose. That purpose determines the functions various subsystems must perform. For example, the purpose of a particular combat aircraft might be to achieve and maintain dominance over land forces by disrupting their ability to continue fighting. This requires that, as a system, the combat aircraft include functions that enable specific altitudes, airspeeds, and maneuvers; processing certain radar information; and acquiring, tracking, and engaging ground targets. While these functions or various subfunctions may be assigned to either humans or machines, they must be present in order for the system to fulfill its purpose.

Mission. Although a system is designed for a particular purpose, that purpose is often stated in relatively global terms. A mission is a specified goal-oriented activity the system is intended to accomplish. For example, an aircraft designed to enable us to disrupt the fighting capability of enemy land forces could achieve its purpose by destroying their supply centers or by attacking enemy troops that are in close proximity with friendly ground forces. These represent two different missions, each of which is consistent with the system's purpose. However, these two different missions may change the specific weapons carried on the aircraft as well as the tactics, techniques, and procedures used by the aircraft's pilot. Therefore, the behavioral analyst must consider not only the system and its purpose but also the specific missions or various ways in which the system is used.

Job. A job is a collection of duties and tasks that are performed by *one individual*. The job is the basic unit used in carrying out the personnel actions of selection, training, classification, and assignment. A job may consist of several, or even many, different duties and tasks, and they need not be related to each other. For example, an electronics technician may also serve as a labor organizer, benefits counselor, and radar operator in addition to primary duties of electronic equipment troubleshooting and repair.

Task Environment. The task environment consists of the cues and conditions that influence how the operator performs a particular task. It includes environmental conditions such as temperature as well as the particular tools, displays, and controls the operator uses to perform the task.

Task. At the simplest level, a task is "A single unit of specific work behavior with clear beginning and ending points that are directly observable or otherwise measurable" (Department of Defense 2001a, ¶6.5.35). As indicated in Table 6.2, tasks are performed for a purpose. Tasks are viewed as system related activities, performed by humans, to achieve specific *goals* and *subgoals* that must be achieved for the overall system to fulfill its mission. Typically, these goals and subgoals are hierarchically nested within a mission and determine the specific tasks that must be performed at a particular time. For example, a commercial airline pilot has the overarching goal of safely transporting passengers to a specific destination. Nested underneath that goal are subgoals such as avoiding air turbulence and maintaining fuel efficiency.

Tasks typically have performance conditions, performance requirements, and performance criteria or standards that must be met in order for them to contribute successfully to mission accomplishment. Performance conditions are the environmental cues that initiate and guide action and factors that enable or constrain action. Performance requirements describe the types of actions and manner of task execution. Performance criteria or standards define the acceptable level of task performance necessary for successful task completion.

Miller (1962) distinguished between task description and task behaviors. Task descriptions describe the general nature of the work and specify the interactions between the operator, the other system elements, and the work environment within a systems framework. They "describe what humans are expected to do" (Nemeth, 2004, p. 187) and are typically stated as high-level functions such as "to detect" or "to maintain." Task behaviors, on the other hand, describe what the operator must actually do in order to accomplish functions such as detect or maintain. Task behaviors describe in detail how work needs to be performed to accomplish a particular function and serve as the primary means for describing the specific instructional content and its sequencing. For the sake of brevity, a systematic distinction between task descriptions and task analysis will not be made. More detailed discussions of this difference are available in Jonassen, Tessmer, and Hannum (1999) and Meister (1985, 1989).

Evolution of Behavioral Task Analysis

Behavioral task analysis is hardly a new process. It is the product of industrial engineering, behavioral psychology, and systems analysis. The industrial engineering influence can be traced back to Frederick Taylor, Frank and Lillian Gilbreth, and

others who systematically analyzed worker behavior during the early 20th century in an effort to increase factory output through the application of scientific management (Annett & Stanton, 2000). Their goal was to identify the most efficient way to accomplish manual work in order to increase worker productivity in the context of the nascent manufacturing technology of the time. For example, the Gilbreths developed a notational system called "therbligs" for "analyzing the motions involved in performing a task . . . . as well as . . . delay" in order to eliminate inefficient motions and wasted time (Ferguson, 2000, p. 1).

This early work demonstrated that jobs could be described as being comprised of a number of distinctive elements, and these elements could be decomposed into tasks and subtasks. It established the foundation for both job analysis and task analysis and identified a number of questions that are still important for task analytic methods. These questions include:

- What is the work performed?
- How do we measure the quality of the work?
- Under what conditions is the work performed?
- How is the work performed?
- What is needed to perform the work?
- How is work performance measured?

During the first half of the 20th century, psychologists, particularly in the United States, focused much of their attention on the analysis of observable behavior. Although competing schools of behaviorism differed in many ways (Bower & Hilgard, 1981), John B. Watson, Hull, and Skinner and their followers believed the foundation for a scientific understanding of behavior rested on the analyses of observable and measurable outcomes associated with specific stimuli, and they eschewed any appeal to unobservable mental processes. Much like the proponents of scientific management, attempts to apply behaviorism to the analysis of work focused on the conditions for and the consequences of behavior. For example, applied behavioral analysis focused on task performance as a chain of overt stimuli and responses (Gilbert, 1962). The result was a conception of human performance as a series of stimuli, responses, or actions, and consequences or outcomes in which these outcomes became the stimuli for subsequent responses. It essentially viewed a task as a linear stimulus–response–stimulus sequence and ignored the role of cognitive processes and knowledge in performing a task. The goal was to determine how to ensure the appropriate response to the specific set of stimulus conditions. This behavioral influence, which dominated American psychology for half a century, viewed work as the assembly of interchangeable parts and human performance as the assembly of specific actions in response to specific stimulus conditions.

Occupational/Job Analysis

Modern job and task analysis began during the 1940s and early 1950s. It was initiated during World War II when large numbers of people had to be trained quickly to operate complex equipment under difficult, life-threatening conditions. Engineers, psychologists, and military subject-matter experts were brought together to develop methods for improving the design of equipment and the methods of training people to use that equipment. Understanding how people used this complex equipment to accomplish specific tasks and how to train people to use that equipment led to modern ergonomics, human factors, and instructional systems theory (Koppes, 2006; Nemeth, 2004).

The first step in meeting these needs was to determine what tasks would have to be taught and to whom. This required a detailed listing of the tasks comprising a specific individual's job or duty. In the years after World War II, these techniques were found useful in organizational analysis (for example, what should a collection of people, such as a brigade or platoon, consist of and what tasks should be performed by which persons in the collection to achieve an overall mission?), and in the process of planning for new hardware systems (for example, what combat and support tasks must be performed and how should these be distributed over the number of crew personnel afforded by a ship's size and berthing facilities?). Once the tasks are identified, the analyst collects task information such as that shown in Table 6.3.

These occupational analysis functions were then consolidated in the 1950s and 60s into organized programs in the military, especially the Air Force. This resulted in establishment of the Air Force's Comprehensive Occupational Data Analysis Program (CODAP), which became a computational effort involving large-scale surveys, data collection, and analysis. The Navy had a similar effort called the Navy Occupational Task Analysis Program (NOTAP). The civilian sector also started similar efforts. Perhaps the largest of these is the activity of the Vocational-Technical Education Consortium of States (VTECS, n.d.), a consortium that conducts job analytic efforts for the purpose of designing career and technical education and training curricula.

Task Analysis and Instructional Systems Development

Behavioral task analysis plays a major role in the needs analysis portion of the training development process. This linkage between task analysis and training is most apparent in the formalization of what has come to be called instructional systems development (ISD).

The post-World War II formalization of human performance led to proceduralized methods for ISD (Branson, Rayner, Cox, Furman, King, & Hannum, 1975), also known as the "systems approach to training," which by the late 1970s had been adopted by all U.S. military services and by many universities,

Table 6.3 Typical Information Collected During Task Analysis

Who performs each task?
For how long? What is the percent of time an individual spends performing the task?
How frequently is the task performed?
To what standard of performance?
In what sequence or combination with what other tasks?
What are the cues for initiation of the task?
What are the hazards and environmental and safety constraints on task performance?
What is the criticality of performance? That is, how essential is correct and complete task performance to overall mission success?
What is the task delay tolerance? That is, what is an acceptable interval between cues and the need to perform the task? For example: bleeding should usually be stopped immediately, but paperwork can wait. Is it possible to bring in other people to perform delayed tasks?
How difficult is the task, or what is the probability of inadequate performance?
How difficult is the task to learn?
Does the task have to be performed correctly by an individual upon first assignment to a job, or is there an opportunity for the task to be performed under supervision?
Are there long periods of non-performance when forgetting may occur?
What are the tools and aids for performing the task? Can job aids be developed which will simplify the tasks, reduce the requirement for training, or increase resistance to forgetting?

corporations, and other training or education-oriented consortia. These instructional systems development/systems approaches to training methods included task analysis as a critical phase in developing instruction and training. Montemerlo and Tennyson (1976) noted that from 1951 to 1976, there were over a hundred different ISD manuals written. Although differing in basic assumptions, emphases, or approaches in the design of training, most included some sort of task analysis. Andrews and Goodson (1980) reviewed sixty models of instructional design and found that 75 percent had an analysis phase that included some process and/or product recommendations concerning the analysis of tasks for which the instruction would be designed.

The trend in the U.S. Department of Defense toward extensive procedural documentation noted by Montemerlo and Tennyson (1976) has not abated. Each of the services has revised its ISD guidance documents several times in the last thirty years, and the Department of Defense itself has consolidated much of this guidance. As of this writing, the current task analysis methodological

guidance is contained in *Performance Specification Training Data Products* (Department of Defense, 2001a) and is supported by the *Handbook for Instructional Systems Development/Systems Approach to Training and Education* (Department of Defense, 2001b). The appendix to this chapter lists some of the current guidance from each of the military services.

These later variants of instructional systems development/systems approach to training guidance provide clarification (if not much improvement) over the earlier methodologies. Although they are often updated to address more modern interactive media, training analysis methods are relatively constant, since training media decisions are typically made after the task analysis is completed. In general, the major activities involved in performing behavioral task analysis are the same as those that began after World War II: Observe performance; try to describe it in words; unpack the description hierarchically into sub-procedures; continue the process until some assumed elemental level of description is reached; identify conditional antecedents and measurable outcomes for each element; and finally consolidate commonalities across the hierarchy.

Cognitive Task Analysis

Cognitive task analysis is rooted in cognitive psychology, which investigates the mental processes involved in activities such as perceiving, remembering, thinking, and problem solving. Between 1950 and 1970, cognitive psychology emerged because of a growing dissatisfaction with behavioristic accounts for such complex activities, and the rapid growth of systems engineering and information theory. Cognitive psychology views the human as an information processor and emphasizes higher-order mental processes as critical components of skilled behavior (see Neisser [1967] for a review of the early stages of information processing). The result is a characterization of human tasks as involving various processes such as perception, pattern recognition, intention, memory storage, knowledge retrieval, mental computation, reasoning, and choice as well as overt action. This led to a new view of task analysis, and a new set of task analysis techniques for identifying cognitive components of task performance.

Relationship Between Behavioral and Cognitive Task Analysis

Behavioral task analysis is primarily concerned with the observable tasks that operators perform successfully to accomplish a particular job as part of a specific system (Kirwan & Ainsworth, 1992). It focuses on what should or must be done to accomplish work (Vincente, 1999) and its primary focus is on identifying specific input-task-output sequences that, if correctly performed, allow the individuals to achieve specific goals. The typical output of a behavioral task analysis is an ordered listing of tasks, subtasks, inputs, activities, outputs, environmental conditions, and performance standards that are heavily dependent upon the specific components of the system (Benyon, 1992).

In contrast, cognitive task analysis attempts to describe or analyze the mental phenomena that are thought to engender specific behaviors. The focus is on the mental representations, underlying knowledge structures, and information processing activities necessary to make decisions and perform actions. Cognitive task analysis helps contextualize behavior for those aspects of the job that are ambiguous, difficult, or involve multiple inputs. It expands traditional or behavioral task analysis by capturing "information about the knowledge, thought processes, and goal structures that underlie observable task performance" (Schraagen, Chipman, & Shalin, 2000, p. 3). It helps to understand and contextualize behavior for work that is complex, ill-defined, or difficult by describing how experts use their knowledge to structure relatively complex ill-defined work and accomplish that work effectively and efficiently.

However, there are significant differences between traditional or behavioral task analysis and cognitive task analysis. Early task analytic methods such as those of Miller (1953) and Flanagan (1954) placed their emphasis on the behaviors or actions that the worker must perform as part of a human-machine system. This view described both the human and the machine portions of the system as subsystems that receive inputs, perform internal operations on those inputs, and provide outputs. Even though these pioneers of task analysis recognized that cognitive processes were inherent in performing tasks, they included these cognitive processes within an overarching system framework and focused on describing the required output or performance as a function of the input or stimuli.

As Stanton (2006) points out, beginning in the 1960s, Annett and colleagues expanded on the importance of cognition in task analysis and provided a direct link to cognitive psychology by emphasizing the importance of goals and subgoals in their development of hierarchical task analysis. They recognized that analyses focused primarily on simple observable behaviors were unable to capture the dynamic nonlinear nature of what people did as work increasingly shifted from hands-on manufacturing to process and supervisory control. Hierarchical task analysis proposed that work consists of hierarchically organized clusters of goals and that workers perform tasks to meet specific goals within a particular goal hierarchy. During this same time, a similar view of the importance of hierarchical organized goals and their importance in human-machine systems was also evolving within the field of control theory (for example, Kelly, 1968).

Technology enables smart machines to perform many highly predictable, procedural tasks, leaving the worker to cope with cognitive tasks requiring inferences, judgment, diagnosis, and decision making (Howell & Cooke, 1989). As a result, it becomes more difficult, if not impossible, to specify procedures "for every possible situation, especially in a world filled with unexpected events" (Norman, 1988, p. 156).

In practice, there is no hard-and-fast line separating behavioral and cognitive task analysis. Modern behavioral analysis includes cognitive tasks because the

scheme for making sense of, or inferences from, the trace of behavior is really a characterization of the cognition underlying task performance. Conversely, cognitive task analysis must start with an observable purpose, mission, and overt performance, and involves observing and analyzing verbal and nonverbal behavior. Contemporary cognitive science is doing very fine-grained task tracing of cognitive events and constructing tasks that elucidate what alternative rules or problem-solution paths people are using while neurocognitive techniques such as functional Magnetic Resonance Imaging (fMRI) offer the promise of making the neural elements of cognition observable (National Research Council, 2008).

Contemporary task analyses are eclectic, involving both behavioral and cognitive techniques. Behavioral task analysis focuses on the identifiable behavioral activity that an operator must perform. Most practitioners recognize that monitoring, detecting, recognizing, and deciding are essential components of any task analysis. Therefore, all successful task performance involves at least some cognitive components "in the sense that perception, decision, knowledge, and judgment are required" (Welford, 1968, p. 21).

Job-Task-Cognition Continuum

There is a continuum of techniques for analyzing jobs and job performance. Task analysts must be familiar with both behavioral and cognitive task analysis in order to understand and describe what is required to accomplish complex work successfully.

If one needs to determine primary job tasks and their characteristics (frequency, criticality, difficulty, conditions under which they are performed, time required to complete, and so forth), then one conducts a job analysis. If one is interested in creating a hierarchical list of job performances from the task to the operant level of performance (discrete steps), one uses a behavioral task analysis. If one is dealing with observable performances that are the result of complex cognitive processes involving interpretation, troubleshooting, decision making, and other forms of problem solving, then one uses a cognitive task analysis to elicit the knowledge, analyze it, and represent it in ways that enable the closure of performance gaps. Analysts frequently use a combination of behavioral and cognitive methods and balance their relative investment in each method based on the nature of work and the final goals of the analysis (Gordon, 1994).

BEHAVIORAL TASK ANALYSIS PROCESS

This section describes the typical stages involved in conducting a behavioral task analysis with several examples of specific applications of behavioral task analysis as well as a number of limitations and pitfalls.

Behavioral task analysis is the process used to identify critical tasks and identify the standards, conditions, performance measures, and other criteria associated with the performance of those tasks. While this section emphasizes the use of behavioral task analysis to support training, the basic principles underlying behavioral task analysis are applicable to the broad spectrum of human system integration activities. It is a critical part of the human systems integration process and is used throughout the life cycle of the system to help allocate functions between humans and machines, identify necessary staffing levels, design human–machine/human–computer interfaces, and assess human performance as well as to develop training and job performance aids.

A training task analysis is typically conducted in an iterative fashion and involves mission analysis, job analysis, and task identification, as well as behavioral and cognitive task analyses. The results of the behavioral task analysis serve as the basis for the development of a training program. In courses that tie the content directly to preparing students for the performance of a mission or job, the analyst documents the performance requirements and develops a task list for the mission/job that may include higher-level tasks such as problem solving, leadership, and management. The analyst then hierarchically decomposes the required performance by looking at the mission, job, or the task itself and cataloging its parts. A result of this phase is the identification of the knowledge, skills, and abilities, aptitudes, or attitudes (KSAs) required for the mission/job/task performance. Then the analyst compares the KSAs the actual jobholder must possess with the KSAs already possessed by the incoming students. The difference between what the students already know and can perform and what the mission/job/task requires them to know and be able to perform defines a training requirement.

Mission Analysis. The goal of the mission analysis is to identify all the major tasks and functions necessary for accomplishment of the overall organizational mission. All instruction should be based directly on mission, job, or education requirements. Mission/job analysis uses data from many sources, including mission statements found in regulations or locally developed statements.

For the military, the Universal Joint Task List (Chairman of the Joint Chiefs of Staff, 2008) provides broad task action descriptions, specifies the conditions affecting performance of the tasks, and provides measures and criteria for performance that comprise the task standards. Each Service and Defense Agency also has developed Service or Agency Mission Essential Task Lists, in some cases down to the level of individual job/task analyses, which also include specific conditions and standards. Each task description typically consists of an action verb, an object of the action, and qualifiers that provide additional detail concerning conduct of the action, conditions, and/or standards.

For nonmilitary organizations, mission, job, and task analyses are often conducted by human resources departments, trade/labor organizations, or governmental labor/commerce departments. Analysts and curriculum developers also make use of management engineering reports, occupational data, and direct observation to determine the actual mission and job requirements. The products of many military analyses are also applicable to nonmilitary jobs; for example, the Air Force has provided a number of task lists for jobs such as Airfield Management and Maintenance Data Systems Analysis to VTECS for use in their state workforce development and assessment programs.

Job-Task Analysis. Job-task analysis is typically done for purposes of job description for personnel functions such as determining hiring qualifications, allocating tasks to various levels of responsibility, specifying promotion paths, etc. Many examples of job-task analysis can be found on the Internet. See, for example, the website of the Oregon Department of Public Safety Standards and Training (DPSST), the website of the *Journal of Nuclear Medicine Technology* (Prekeges, 2003), and the Texas Commission on Law Enforcement Officer Standards and Education (1997). (Website addresses are in the References section.) In the military, analyses have been done (and redone) for most jobs. These are found in job descriptions such as the Air Force Occupational Standards (AFOS), Army and Marine Corps Military Occupational Standards (MOS), and the Navy Enlisted Occupational Standards (NEOCS).

As part of this process, *Instructional Systems Development/Systems Approach to Training and Education* (Department of Defense, 2001b) recommends development of a mission matrix, denoting who (what team or individual) is responsible for each task. Typically, this is done in a hierarchy of more subordinate tasks at each lower level of command. Higher-level tasks are often "collective" tasks, when they require more than one individual to complete, and lower levels in the hierarchy identify discrete parts of collective tasks assignable as standalone tasks to individuals. Analysts identify tasks within a system and mission context to provide the purpose of the task and the goals that the operator is trying to achieve in performing that task. They then decompose tasks to subtasks based on a number of factors such as the purpose of the analysis, the complexity of the task, and the consequences of poor task performance.

Figure 6.2 illustrates the general structure of collective and individual tasks associated with most complex systems. As mentioned earlier, a system frequently has a number of missions, and those missions usually require a combination of collective and individual tasks.

The point of the collective task analysis is to (1) identify the conditions, standards, and actions for work-group-level tasks so that they can be assigned to the appropriate level of command or supervision and (2) separate individual

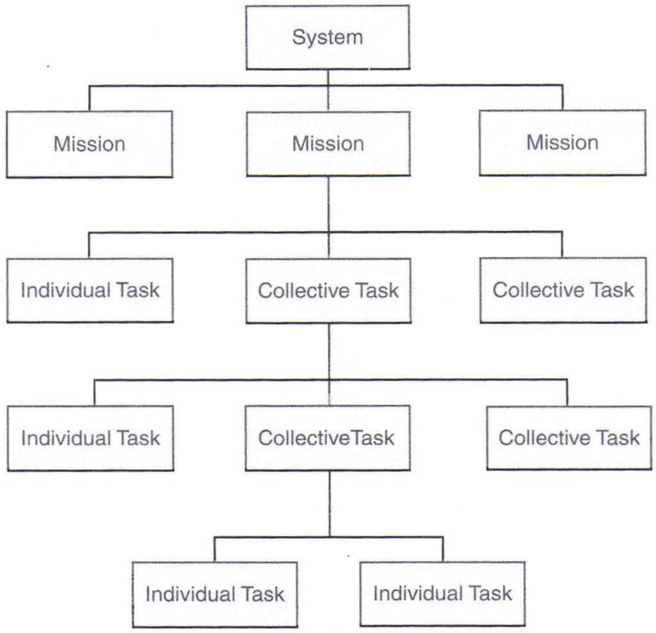

Figure 6.2 Collective and Individual Tasks Are Part of Most Complex Systems.
Adapted from TRADOC, 1999

tasks so they can be further analyzed for purposes of doctrine development, equipment design, or training.

A behavioral task analysis involves defining and describing the tasks that individuals must (learn to) perform. Although this chapter focuses on describing how task analysis is used to identify training requirements, the basic concepts are relevant to the analysis of any human-centered system. For example, a related set of task-based methods has come from the trend toward "user-centered" system design, where the activities a user (for example, a computer user) tries to accomplish are analyzed to design better user interfaces and processes (Osga, 2003).

BEHAVIORAL TASK ANALYSIS METHODS

Unfortunately, behavioral task analysis is not an exact science. It involves the application of both accepted procedures and analytic judgment to describe how people perform their work. As the work being analyzed becomes more complex, the analyst's experience and theoretical orientation play increasingly important roles in determining the final product. However, most behavioral

task analyses share a number of common features and techniques that are described below.

When performing a behavioral task analysis, the analyst typically performs a number of activities that include:

- Reviewing system and mission documentation;
- Interviewing subject-matter experts;
- Observing people performing tasks;
- Recording information;
- Organizing information and observations; and
- Documenting and validating the analysis.

Except for very simple analyses, these activities are usually performed in an iterative manner. The goal is to develop an in-depth understanding of what is done and how it is done. Typically, one begins by reviewing documents that describe the system and its mission. These documents may include mission need statements, business plans, system specifications, scenario descriptions, use cases, and technical drawings. These documents provide critical information about the displays, controls, interfaces, and task conditions. They also allow the analyst to identify potential questions to ask subject-matter experts and highlight areas of special concern to watch as people perform their tasks.

The next step typically involves structured interviews with subject-matter experts, either individually or in small groups. These knowledgeable individuals know how to perform the task or similar tasks. There are numerous ways to conduct these interviews. One approach is to simply have the subject-matter expert list the tasks in sequence as they are performed within a mission context. Another approach is to have the subject-matter expert provide a highly detailed verbal protocol. In addition to describing the actual behaviors that must be performed, it is also desirable to have the subject-matter expert describe the stimuli that cue the start and completion of the task as well as those stimuli that allow her to monitor successful task progress. There are obviously a number of variations on these approaches. The analyst may rely solely on verbal description or combine verbal descriptions with actual task performance using simulated or actual equipment. The analyst may also obtain detailed recordings of what the subject-matter experts actually did and compare those to what the subject-matter experts verbally described. Selection of a specific approach depends upon the complexity of the mission and the associated behavioral tasks, the purpose of the analysis, and the experience of the analyst.

Whichever approach the analyst chooses, selecting subject-matter experts is often a challenge. It is difficult to define expertise and it is often difficult to gain access to the true experts in a field. Some subject-matter experts also have difficulty

generalizing to new systems that are under development and frequently will remain focused on describing tasks as they are performed using the current system.

If possible, observing typical operators performing the task as individuals or crewmembers is extremely valuable. If the task is a collective task, team members should perform their normal roles while carrying out the task. This allows identifying discrepancies between the expert's view of the task and the way the task is routinely performed by "average" operators. It also allows identifying where there is the potential for performance problems based on workload, equipment layout, or underlying skills.

After tasks to be trained are identified, a more detailed analysis of each task is performed. Task analysis is the process of breaking a task down to identify the:

- Component steps of a task;
- Sequence of those steps;
- Conditions under which the task will be performed (for example, at night, in the field);
- Task cues; and
- Standards of performance that must be achieved, expressed in terms of accuracy completeness, sequence, or speed.

There are many other methods that have been developed over the past fifty years. Carlisle (1986, 1989) gives many observational and analytic methods. Table 6.4 lists methods and brief descriptions of techniques given by Carlisle and others.

Obviously, this entire process must be documented and analyzed. It is not at all uncommon for a complex system to involve hundreds of tasks. Therefore, the analyst needs to have some systematic means of identifying the task. There

Table 6.4 Behavioral Task Analysis Methods and Descriptions

Method	*Description*
Interview Analysis	Interview job performers to elicit task descriptions. (Carlisle, p. 24)
Card-Sort Analysis	Have job performers sort cards containing actions and objects. (Carlisle, p. 28)
Task-Matrix Analysis	List objects in left column, provide actions across top row. Each cell is an action/object pair. (Carlisle, p. 32)
List-Expansion Analysis	Decompose actions into sub-steps. (Carlisle, p. 36)
Daily Log Analysis	Job performers keep a log of everything they do. (Carlisle, p. 39)

(Continued)

Table 6.4 (*Continued*)

Method	*Description*
Walk and Talk Analysis	The analyst "shadows" the job performer and elicits narrations about what is being done. (Carlisle, p. 42)
Job Function Analysis	Provides standardized categories that can be used to identify and organize specific tasks. Analyst and master performer review possible job functions to determine task statements. (Carlisle, p. 45)
Performance Deficiency Analysis	Analyst prepares "what is" and "what should be" chart for job performance based on deficiencies in process and/or product. (authors)
Risk Assessment	Done after the task inventory is compiled to determine the importance and difficulty of each task. From this assessment the analyst can target tasks for further analysis and training. (Carlisle, p. 50)
Performance Probe Analysis	Assess the information, resource, and motivation requirements of the job and the worker in order to suggest needed improvements. (Carlisle, p. 128)
Ergonomic Analysis	Define the cognitive and physical "fit" of the person to the job tasks. (Carlisle; authors)
Problem Analysis	Use description and analysis to determine the underlying reasons for faulty performance. (Carlisle, p. 123)
Job Satisfaction Analysis	Determine how meaningful the job is to the workers. The job can be redesigned based on the analysis, to make it more satisfying. (Carlisle, p. 133)
Paradigm Analysis	Dividing the entire job into component parts. (authors)
Process Charting	Recording and categorizing the steps in a task. (Carlisle, p. 71)
Flow Charting	Shows the sequential actions and decisions in a complex process. It reduces complexity by showing a likely set of actions and simple decisions. (Carlisle, p. 84)
Operation Charting	Used to record, categorize, and improve the detailed motions and senses involved in skilled jobs. (Carlisle, p. 77)
Decision Technique	The decision technique is used when a task is essentially non-sequential or when various decisions must be made, based on the symptoms of a particular situation, in order to select the correct procedure. This

	technique is ideal for troubleshooting and diagnostic tasks. (Carlisle, p. 96)
Stimulus-Response Charting	Used to describe task steps in great detail. It is important when tasks are very complex, involving numerous people, data inputs, or decisions. (Carlisle, p. 65)
Picture Technique	Used when a drawing or photograph of the task makes it easier to analyze and understand how the task is done. (Carlisle, p. 92)
Critical Incident Technique	Used to identify the critical job requirements that are the difference between doing the job correctly and doing it incorrectly. The worker's actual performance is reported, compared, and classified as effective or ineffective. (Carlisle, p. 119)
Learning Hierarchy Technique	Used to order and sequence tasks according to logical relationships. This ensures a correct learning sequence. (Carlisle, p. 178)
Operator Function Modeling	Modeling tasks in complex and dynamic systems. Result is a network diagram showing how human operators accomplish simultaneous activities. (authors)
Operational Sequence Diagramming	Provides a graphical method of task analysis aimed at "describ[ing] clearly the functions of the system integrating all potential hardware requirements." (Walley & Shepherd, 1992, p. 18)
Time Line Analysis	Time line analysis identifies how much time a task will take in order to determine if the task can be completed within the available time. (authors)
Algorithmic Analysis	Analyzes the procedure used to perform the task as if it were a computer program. (authors)
Equipment Analysis	Determine what equipment needs to have done to it for maintenance or fault prevention. (authors)
Interface Analysis	Systematically explore all possible inputs/actions to a computerized task interface. (authors)
Design Analysis	Analyze the design of a system to determine its operational requirement. (authors)
Design Interview	Interview designers of a system to elicit their description of intended operation. (authors)

Definitions adapted from Kenneth E. Carlisle (1986) with page numbers. In some cases, where noted, the definitions were developed by other authors, including the authors of this chapter.

are a number of templates available for recording the information collected during a task analysis. Table 6.5 illustrates one such template. In addition to capturing a written description, additional products such as sequence diagrams, flow charts, and task hierarchies are typically produced as part of the analysis.

Table 6.5 Routine Automotive Maintenance Task

Task Number	*Task*
1	Perform routine automotive maintenance
1.1	Maintain fluid levels
1.1.1	Maintain transmission fluid level
1.1.1.1	Check level
1.1.1.1.1	Start engine and run until normal operating temperature is reached
1.1.1.1.2	Locate transmission dipstick
1.1.1.1.2.1	Visually search engine compartment
1.1.1.1.2.2	If not located, consult maintenance manual
1.1.1.1.2.2.1	Locate engine compartment diagram in manual
1.1.1.1.2.2.1.1	Search list of figures for "engine compartment"
1.1.1.1.2.2.1.2	If not located, search contents for "maintenance"
1.1.1.1.2.3	Search diagram for label "transmission dipstick"
1.1.1.1.2.4	Match diagram to actual engine compartment
1.1.1.1.3	Remove dipstick
1.1.1.1.4	Remove fluid from dipstick by wiping with rag
1.1.1.1.5	Re-insert dipstick until it is inserted as far as possible
1.1.1.1.6	Remove dipstick
1.1.1.1.7	Check level of fluid against dipstick gradations
1.1.1.1.8	Wipe dipstick, reinsert
1.1.1.2	Add fluid as necessary
1.1.1.3	Recheck level
1.1.2	Maintain oil level
1.1.3	Maintain coolant level
1.1.4	Maintain brake fluid level
1.2	Maintain proper tire pressure
etc.	

DESCRIBING BEHAVIORAL TASKS

Consider a vehicle mechanic whose job includes performing "routine automotive maintenance." The mechanic's goal is to maintain the vehicle in accordance with published standards. In order to achieve that goal, the mechanic must perform a number of tasks and associated subtasks. Table 6.5 shows a hierarchical breakout of some of those tasks and subtasks. It also illustrates a typical numbering convention for hierarchical task decomposition.

Two high-level tasks associated with routine automotive maintenance are maintaining proper fluid levels and tire pressure. Table 6.6 lists these high-level tasks as Tasks 1.1 and 1.2, respectively. Each task is recorded using an action verb (explaining what the behavior is), an object (to which the action is applied or performed), and qualifiers or additional information clarifying the intent of the task. Good task statements are clear, complete, and concise. Often, the most difficult part of this process is finding the right action verb that best indicates the behavior involved. Many task analysis guidebooks provide lists of action verbs to help precisely specify behavior. Table 13 of Mil-HDBK-29612-2A (Department of Defense, 2001b) provides a list of action verbs as well as typical learning objectives. Jonassen, Tessmer, and Hannum (1999) illustrate the use of syntactic analysis of these verbs, objects, or qualifiers to identify clusters of tasks that share common characteristics in order to structure a training curriculum.

Table 6.5 also shows how each higher-level task can be decomposed into separable subtasks. For example, maintaining proper levels of transmission fluid (1.1.1), oil (1.1.2), coolant (1.1.3), and brake fluid (1.1.4) are primary subtasks associated with the higher-order task of maintaining fluid levels (1.1).

These subtasks can be broken down into procedural steps such as checking the level of transmission fluid (1.1.1.1) and the specific actions required to check the level of transmission fluid such as running the engine (1.1.1.1.1) and locating the transmission dipstick (1.1.1.1.2). If necessary, tasks such as locating the transmission dipstick can be further decomposed into more detailed procedural steps that include alternative tasks, for example, what to do if the mechanic cannot locate the dipstick (1.1.1.1.2.2).

After the tasks and procedural steps are identified, the following are specified:

- Conditions under which the task will be performed. In this case, the task would be performed in a typical automotive service facility;
- Task cues. In this case, cues might include assignment of the task by the service manager, observation of a fluid leak, or complaint by vehicle owner; or

- Standard of performance that must be achieved. In this case, the accuracy standard would be that the fluid is filled to the correct level. A speed standard, such as "within ten minutes," might also be used.

Pitfalls and Problems

Over-Analysis. In the example above, there are already eight levels of analysis. As Table 6.5 shows, tasks can be decomposed into increasingly smaller subtasks much like a Russian matryoshka nesting or stacking doll until the analyst reaches a "logical stopping point." Obviously, this process can continue to ridiculously fine levels of detail, depending on the requirements of the task and the assumed preparation level of the trainees. One rule for stopping the decomposition process is to continue until actions are reached which the trainee can perform without specific instruction. Annett and Duncan (1967) proposed what is known as the "P × C rule" as a means of defining this stopping point. According to this rule, each task is evaluated based on the probability of inadequate performance and the cost to the system of inadequate performance. If the resulting product is unacceptable, the task is decomposed into subtasks and the P × C rule is applied to each subtask. This process continues until the probability of inadequate performance or the consequences of inadequate performance are acceptable. While this rule suggests a rigorous criterion, it should be remembered that in most cases both the probability of inadequate performance and its consequences are based on expert opinion and rarely involve precise measures. Although the P × C rule is not as precise as one might hope, it does provide the analyst with a good rule of thumb—if a task is highly unlikely to be performed incorrectly, then a more detailed analysis of that task will not significantly increase our understanding of what the operator must do to successfully accomplish that portion of the job.

Paradoxically, though, continued finer-grained analysis can overcomplicate the whole process: subordinate steps often seem more complex than higher-level tasks and they also become more "cognitive." For example, "checking fluid level with a dipstick" is quite a simple task, while locating information in a technical manual can be much more difficult, and visual search, when analyzed in terms of eye movements, is surprisingly intense.

Completeness and Accuracy. In the example above, a good maintainer will also inspect the fluid for color (evidence of oxidation) and contamination in Step 1.1.1.1.7. How does the analyst know that a critical step has been left out? Similarly, how does the analyst know that the process or steps of procedure are actually correct?

Both completeness and accuracy can present serious problems when task analysis is performed by so-called human-performance specialists who are not

content specialists, and this is true for both behavioral and cognitive task analytic approaches. The standard approach to this problem is to use subject-matter experts to assist with and review the analysis. However, this often just shifts the problem because the putative expert is often a person who can be spared from actual operations, rather than the most capable, and there is generally no independent way to verify the expertise of the putative expert. A better way is for a verified content expert to do the analysis since it is often easier to teach a content expert task analysis than to teach an education specialist highly technical job content. It is important that content experts be not only expert performers, but that they also understand the theory and/or science underlying the tasks and the systems that are implemented in the real world. For example, in analyzing tasks involved in operation of a radar, the content expert should understand the underlying physics of electromagnetic wave propagation and reflection, the reflective properties of the targets the radar is designed to detect, the real-world design and implementation of radar systems (because there are always design compromises from theoretical optimality), as well as the operational implications from physical and design constraints. In the end, accuracy and completeness depend on the perspicacity of the analyst, and anyone who has ever done a complete task analysis usually ends up knowing more about the tasks than most job experts know.

For maintenance/repair tasks, another approach to ensuring completeness is to analyze the equipment and its design. What does the equipment need to have done to it in order to maintain or repair it? These tasks should NOT be analyzed by asking performers what they do, unless there is some independent way to verify that they actually understand what they are doing. Rather, maintenance and repair tasks are best identified and analyzed by examining the design and implementation of the device to be maintained, and the quality statistics that are usually accumulated over time by competent organizations. For example, the majority of maintenance requirements of a pump are governed by the materials and design of the pump, especially the pump seals and bearings, and the pump's operational history. Therefore, the best course is to consult the designers and manufacturers of the pump to identify maintenance requirements, to confirm maintenance histories comply, and verify that there is no unexplained flaw that has skewed the data. Probably the best implementation of this method comes from the U.S. Navy's nuclear submarine program. The training analysis and design methods are documented in NAVEDTRA 131, Personnel Performance Profile Based Curriculum Development Manual.

A similar approach also can work for operator tasks. The analyst should first consult the tactical or operational requirements that a particular system was designed to meet, then consult the designers, who had operations in mind as they designed the system, to identify what operator controls are built into the system to support the operational tasks that were envisioned during design. Again, it may be

risky to consult current job performers as "experts" unless there is independent verification of their understanding of the underlying theory, system concept, and system design, as well as operational employment. Sometimes "expert" misconceptions have led to poor task analyses. For example, a senior Army air defense radar operator told trainees not to use a control to correct for refractivity of the atmosphere because doing so would "bend the radar beam" (Larson, personal communication, 1995). (Actually, the control aimed the antenna at a slightly different elevation in anticipation of atmospheric refraction.)

Oversimplification. The emphasis on observable steps often leads to omission of decision making, reflection, deduction, integration, and other so-called "mental" or "cognitive" tasks. This can often lead to detailed specification of trivia and neglect of the "hard parts" of the task. For example, an analysis for the task "Write a Great American Novel" might be:

1. Obtain an American English dictionary.
2. Choose words from the dictionary.
3. Arrange words in proper order.
4. Repeat 2 and 3 until novel is complete (Note: Words may be used more than once).

There are several ways to handle such situations. One is to use the methods of cognitive task analysis, described by Villachica and Stone (Chapter Seven). Another is to analyze these tasks more schematically and procedurally, by specifying the behaviors involved at finer-grained levels of analysis. For example, novel writing may involve several higher-level but nonetheless behavioral subtasks:

1. Develop overall plot outline.
2. List major and minor characters.
3. For each major character, write actions consistent with plot outline that give insight into character motives.
    3.1. For villain, write scene involving premeditation of crime.
    3.2. Write description of earlier life events leading to antisocial outcome.
    3.3. Write scene showing gratification with nefarious result.

While this approach may lead to formulaic writing, it at least expresses the specifics of what needs to be written.

Commonalities. Behavioral task analysis may ignore the connections among related tasks. This can lead to instruction, especially for introductory material, that is a series of isolated topics. After several top-level tasks are completed, the analyst will likely notice commonalities across different task hierarchies. For instance, if the analysis in the automotive example above were pursued, there

might be several different task-subtask decompositions that call for consulting the maintenance manual. When this occurs, the standard practice is to designate such common tasks as "KSAs" (knowledge, skills, and abilities) as in "knowledge of maintenance manual" or "skill in locating information in a maintenance manual" or "ability to locate and interpret graphical and figural information in a technical publication." In general, this means that these supposedly more basic KSAs will not be further analyzed, and instead become enabling prerequisites for the to-be-designed training. Alternatively, similarities in the analysis can all be grouped together, analyzed once, and later taught as a common prerequisite to the otherwise-unrelated higher-level tasks.

Over-Emphasis on Procedural Skill. In the examples above, the task breakdowns resulted in specifying procedural steps in greater and greater behavioral detail. This is relatively easy when the job consists of highly proceduralized steps that involve observable behaviors. However, many jobs also require cognitive tasks such as problem solving, and the analyst often needs to identify behavioral objectives for these tasks as part of these tasks. For tasks such as problem solving, there are other ways to decide what behavioral objectives should be included in the training program. These include various forms of algorithmic analysis, and the use of model- or theory-based characterizations of tasks to provide a basis for determining what subtasks should be included in the analysis.

For example, problem-solving tasks can often be grouped by similarity of solution methods, for example, Hively, Patterson, and Page (1968). Here, the idea is to specify solution methods or processes in advance (by looking at rules or algorithms for solving problems), then use these as a basis for understanding the behavior. This approach was first described for mathematical or arithmetic tasks (Polya, 1957) and then extended to the diagnosis of incorrect performance during training (Brown, Burton, & Larkin, 1977; Scandura, 1983). Another approach is to use mathematical or qualitative models that represent parts of tasks (de Kleer & Brown, 1983; Forbus, 1981), and then use these as a basis for identifying what knowledge is needed to execute the task even though this makes the analysis more "cognitive."

BEHAVIORAL TASK ANALYSIS APPLICATION EXAMPLES

Interactive Multisensor Analysis Training. Wulfeck, Wetzel-Smith, and Dickieson(2002) provide an example of a task analysis and development of training objectives drawn from sonar training. The model-based scientific visualizations in the Interactive Multisensor Analysis Training (IMAT) project have also enabled a new approach to the specification of training tasks for acoustic, electromagnetic, and electro-optical systems.

As seen earlier, the traditional method for analyzing a task is to identify the components of a task by hierarchically decomposing it into subtasks, skills, and knowledge. Training is then based on these units, and they are tested mostly individually. This can often result in a focus on low-level detail in training, so that tasks are independent and serial, with limited cause and effect explanation as to how those topics interrelate. This approach often leads to instruction containing descriptions of complex phenomena and large amounts of factual data with little contextual reference. Feltovich, Spiro, and Coulsen (1991) point out that teaching isolated topics or "compartmentalizing knowledge" makes it more difficult for students to integrate their knowledge or to generalize knowledge in new applications.

Further, when task analysis results in introductory instruction for complex interrelated tasks as a series of isolated topics, there may be a detrimental effect on future learning because oversimplification early in training may result in later difficulty due to the need to unlearn the too simple explanations and replace them with more mature knowledge.

The Interactive Multisensor Analysis Training project has led to a process for conducting conceptual analyses, which involves the following general steps:

a. Determine the most complex performance problem for which a training solution is required.
b. Identify and refine the variables, and dimensions along which they vary, necessary to model the problem.
c. Obtain or develop mathematical and/or qualitative-process models that relate these variables/dimensions and specify how they interact.
d. Design an interface and display system that facilitates understanding of the variables and their relationships.
e. Identify problem scenarios (cases) using the resulting simulation.
f. Validate the problem scenarios by working through them with operators and tacticians.

In general, the process of constructing and validating model-based visualization systems identifies the underlying critical variables, their relationships, and their tactical implications. These then become the enabling concepts and tasks in the analysis. This analytic methodology has been applied to acoustic, electromagnetic, and electro-optical systems and has successfully identified training requirements for developmental systems still in test and evaluation.

Mission Essential Competencies^{SM}. The Mission Essential Competencies^{SM} work of the Air Force Research Laboratory represents a new approach to capturing job performance requirements (Alliger, Beard, Bennett, Colegrove, &

Garrity, 2007). Mission Essential Competencies^{SM} link knowledge, skills, and individual experiences in order to understand the performance requirements associated with a specific job. This approach combines elements of behavioral and cognitive task analyses in order to identify performance requirements at different levels of abstraction. At the highest level is a *Mission Essential Competency*, which describes a higher-order individual, team, or inter-team competency needed for successful mission completion. An example of a mission essential competency for an F-15 pilot is to *intercept and target enemy aircraft*. At the next level of abstraction are the *Supporting Competencies*, the generic competencies that enable completion of one or more mission essential competencies such as being able to *clearly, concisely, and correctly communicate information*. The lowest level of abstraction consists of the *specific knowledge* (information or facts) and *skills* (compiled sequence of actions) that are associated with a competency such as *knowing the rule of engagement*. Once this abstraction process is completed, the process also identifies the specific *experiences* that are important for learning, refining, or sustaining those competencies.

Mission Essential Competencies^{SM} provide a hierarchical scheme that captures the high-level competencies needed for a particular job and then systematically decomposes those competencies into the specific knowledge and skills that underlie those competencies. They focus on the competencies needed to accomplish a particular mission and are developed in facilitated workshops with subject-matter experts. Competency analysis have been conducted across a wide variety of missions and are currently being used to help identify options and requirements for training environments, training devices, and training frequency.

Driving. Behavioral task analysis is also valuable in fields such as computer science and robotics, as they attempt to develop autonomous and/or intelligent systems. Task-analytic methods help inform the development process by describing the functions such systems must perform and the range of conditions under which that performance occurs.

An example is the use of a behavioral task analysis to support development of more capable autonomous vehicles (National Institute of Standards and Technology, 2003). The program used an analysis of human driving behavior (McKnight & Adams, 1970) to help them develop a hierarchical taxonomy of driving tasks, identify stimulus events, and estimate complexity as part of creating the computer algorithms and data structures necessary to develop an autonomous vehicle. The McKnight and Adams task analysis was done to support development of driver education objectives and provided a detailed description of forty-five passenger car driver tasks and fifteen hundred driver behaviors. These tasks were broken down into two major categories: on- and off-road tasks. The on-road tasks and subtasks were classified as basic

control tasks, general driving tasks, and situation specific tasks. Supporting material for these tasks included estimates of performance limitations, criticality, and underlying skill (perceptual, motor, or cognitive). Table 6.6 shows the major on- and off-road tasks identified by McKnight and Adams and provides a few examples of the subtasks and behaviors associated with these major tasks.

Table 6.6 Examples of Tasks and Subtasks

Task Categories	*Task Category*	*Subtasks*	*Goal*	*Actions*
On-Road Tasks				
	Basic Control Tasks			
		Steering		
		Skid Control		
			Takes Preventive Measures to Avoid Skids	
				Enters curves or turns at moderate speeds
				Attempts to avoid panic stops or hard braking if possible
			Attempts to Arrest Skid	
				Keeps foot off brake
	General Driving Tasks			
		Surveillance		
		Navigation		
		Urban Driving		

Task Categories	*Task Category*	*Subtasks*	*Goal*	*Actions*
	Tasks Related to Traffic Conditions			
		Passing		
		Lane Changing		
	Tasks Related to Roadway Characteristics			
		Lane Usage		
		Weather Conditions		
	Tasks Related to the Car			
		Hauling and Towing Loads		
		Pushing and Towing		
Off-Road Behaviors				
	Pre-Trip Planning			
		Planning		
		Loading		
	Maintenance Tasks			
		Routine Care and Servicing		
	Legal Responsibilities			

Aircraft Maintenance. In the late 1990s, Northwestern University conducted an aviation maintenance technician job/task analysis for the Federal Aviation Administration (Adam, Czepiel, Henry, Krulee, Murray, & Williamson, 1997). The goal of this analysis was to obtain data to update the core curriculum requirements for obtaining an Aviation Maintenance Technician Certificate.

One interesting aspect of this analysis was its magnitude. This analysis illustrates some of the complexities in analyzing the tasks associated with a complex job across an entire industry. Unlike most job task analyses, which focus on a particular job within a particular organization, this analysis obtained data on over three hundred tasks from 2,434 surveys administered to respondents at eighty-four different aviation facilities, ranging from major airlines to small general aviation shops.

The overall objectives of this analysis were to:

- Identify tasks that broadly define the job of an aviation maintenance technician;
- Survey a representative sample of aviation facilities to determine
  - Task relevance/importance,
  - Tasks that reflect technology change, and
  - Similarities and differences between different segments of the industry; and
- Facilitate revisions to aviation maintenance technician school curricula.

One of the challenges in conducting such a broad analysis is determining the number of tasks to include in the survey. The analysts had to find an appropriate balance between an exhaustive listing of all possible aviation maintenance technician tasks, which would be too long for a survey, and a shorter list that would sacrifice performance details. To achieve this balance, the analysts focused on three major task categories:

- Check, Test, Service, Inspect
- Repair, Replace, Modify, Calibrate
- Troubleshoot

These three major categories were then grouped into twenty Air Transportation Association subject categories such as landing gear, flight controls, or engines. Respondents rated each task along three dimensions:

- Frequency of task performance—less than once a quarter, quarterly, monthly, weekly, daily;
- Criticality to flight operations—negligible, low, average, high, extremely high; and
- Difficulty to learn—not difficult, somewhat difficult, moderately difficult, increasingly difficult, very difficult.

The surveys contained brief descriptions such as "not critical to the continuation of flight" or "task is complex and involves multiple steps" to provide common anchor points for the respondents.

In their discussion of the results of this task analysis, Adam and his associates (1997) highlight the differences between different industry segments in how frequently an aviation maintenance technician performs a particular task. Base maintenance facilities, such as those operated by large airlines, typically involve a high degree of specialization. As a result, technicians typically perform a narrower range of tasks than those working in a general aviation facility. Because of this specialization, technicians at major base facilities are likely to report performing a narrower range of tasks or performing some tasks less frequently than technicians at less specialized facilities. Task analysts need to be alert to such differences in developing their data collection protocols. Selecting an inappropriate segment of the industry or experience level can result in data that misrepresents how frequently certain tasks are performed. This frequency effect could also inadvertently influence the perceived occurrence or difficulty of those tasks.

TECHNIQUES AND TOOLS FOR BEHAVIORAL TASK ANALYSIS

Performing and documenting a task analysis to support system design, job/organizational analysis, or training is often a difficult and time-consuming process. Not only must the analysts identify goals, determine the appropriate level of decomposition, and describe the associated tasks and actions, but they must also document this information so that it can be used to enable effective human performance. As the system becomes increasingly complex, it becomes harder to grasp the interrelationships between various levels of decomposition and to provide the necessary documentation.

Analysts have traditionally relied on paper and pencil as the primary media for recording the results of this work. Even when software tools are used, their primary purpose has been to facilitate data entry, as opposed to assisting the analysis in the actual conduct of a behavioral task analysis. Once the data are captured, analysts must analyze, synthesize, format, and present the results. The synthesized results are typically presented in text format accompanied by either graphical or tabular material. The widespread availability of personal computers and relatively inexpensive graphical (for example, Visio™) and spreadsheet (for example, Excel™) software has greatly reduced the work involved in keeping the data organized and formatting it for presentation.

Computer Aids for Task Analysis

Comprehensive Occupational Data Analysis Program (CODAP). The Comprehensive Occupational Data Analysis Program represents an empirical approach to occupational analysis developed during the 1980s. The underlying assumption of CODAP is that jobs must be defined in terms of the tasks performed by the workers. Using task statements and background information, CODAP sought to provide a tool kit of computer programs, analysis guidelines,

and a theory-based approach to job and occupational analysis. The goal was to provide a common foundation that would help organizations perform human resources management functions such as recruitment, selection, classification, training, and job design. Background material on CODAP is available from several online sources (http://www.codap.com/faq.htm# what; http://www.icodap.org/; and http://www.metricanet.com/groups/codap/index.html).

O*NET. The U.S. Department of Labor has developed an extensive job analysis database of occupational requirements, tasks, and job performer skills and abilities, called O*NET. It is the nation's primary source of occupational information (Department of Labor Employment and Training Administration, 2008). Publicly available online access to the O*NET database allows users to explore occupations, tasks, and knowledge and skill requirements at http://online.onetcenter.org. It includes the ability to relate occupations to other job classification systems such as those in the military. O*NET should be used at the start of any behavioral task analysis.

The Authoring Instructional Materials (AIM) System. The AIM system is a set of computer-based tools for curriculum design and instructional materials preparation. It was originally proposed as a developmental project in the late 1970s, and early versions were implemented and fielded through the 1980s (Wulfeck, Dickieson, Apple, & Vogt, 1992). In general, the idea was to use computer interviews to conduct a dialog with subject-matter specialists to identify and analyze training tasks, then to organize them and their subordinate and superordinate relatives in a relational database. This way, the links among tasks, subtasks, learning objectives, instruction, and technical documentation could be maintained much more efficiently than by traditional methods. AIM development continues to the present time, and AIM versions currently support the Navy's approach to instructional systems development documented in NAVEDTRA 130/131, and the Navy's Integrated Learning Environment. Over 300,000 hours of formal training courseware have been supported by the AIM system. Current AIM information is available at https://ile-help.nko.navy.mil/ile/content/supportapps/aim.aspx.

Automated Systems Approach to Training (ASAT). The U.S. Army's ASAT (Automated Systems Approach to Training) is a software application that is used for Army training and development, support, and management functions. It operates as a training information system, a tool for decision making, and a training development product production system. It has modules that support both collective and individual task development, and then collective and individual training publications, lesson plans, and other documentation. The system is described at www.asat.army.mil.

IMPRINT. The U.S. Army Research Laboratory has developed an Improved Performance Research Integration Tool (IMPRINT), a discrete event simulation tool for analyzing human performance in system design and acquisition. IMPRINT's website states, "Task-level information is used to construct networks representing the flow and the performance time and accuracy for operational and maintenance missions. IMPRINT is used to model both crew and individual soldier performance. For some analyses, workload profiles are generated so that crew-workload distribution and soldier-system task allocation can be examined. In other cases, maintainer workload is assessed along with the resulting system availability. Also, using embedded algorithms, IMPRINT models the effects of personnel characteristics, training frequency, and environmental stressors on the overall system performance. Manpower requirements estimates can be generated for a single system, a unit, or Army-wide. IMPRINT outputs can be used as the basis for estimating manpower lifecycle costs." It is described at: http://www.arl.army.mil/ARL-Directorates/HRED/imb/imprint/Imprint7.htm.

IMPRINT uses a discrete event simulation program called "Micro Saint Sharp" from Macro Analysis & Design (MAAD). MAAD also has developed the Integrated Performance Modeling Environment (IPME), a simulation environment for examining human performance in complex task situations. It contains a collection of tools for describing, simulating, and analyzing operator tasks. IPME is described at: http://www.maad.com/index.pl/ipme.

Multimedia Video Task Analysis™. Multimedia Video Task Analysis™ (MVTA™) was developed by Professor Robert G. Radwin and Dr. Thomas Y. Yen in the Ergonomics Analysis and Design Consortium at the University of Wisconsin-Madison to help automate time studies of observable behaviors (see http://mvta.engr.wisc.edu/). MVTA allows interactive study of activities recorded on a computer-based video system.

TaskArchitect™. TaskArchitect is a computer-based tool for task analysis for complex system design or to create documentation or training materials (see http://www.taskarchitect.com/products.html). TaskArchitect provides graphical and textual tools that support entering and describing tasks and the hierarchical relationships among them. TaskArchitect captures the relationships between tasks and can redraw the analysis automatically after every edit. Task tables and task diagrams are linked together to allow display of either format. It supports both the creation of indented lists of tasks and task diagrams as well as the dynamic reordering of tasks and their relationships. Parent and sibling selection, cut and paste, drag and drop, and task references are supported in all analysis diagrams in order to allow the user to reshape and duplicate areas of the analysis quickly and easily.

The company claims that TaskArchitect allows on-the-fly interaction with subject-matter experts to very quickly produce finished analyses. The system also provides for export of data to other analysis tools like IPME, or to graphical tools like Visio™.

Mindmapping and Concept Mapping. The idea of organizing relationships among concepts, or words, or object-definitions, or familial relationships, or taxons into graphical (usually two-dimensional) "maps" is many centuries old. More modern conceptions of such "linked node" relationships were formalized by Collins and Quillian (1969) originally as a cognitive theory of memory, called "Semantic Networks." Since then much work in the fields of artificial intelligence and cognitive science has explored and developed these ideas. In addition, these techniques have been popularized and in some cases commercialized as so-called "concept maps" or Mind Maps™. Today, computerized tools are available to aid in the construction of linked-node diagrams. While these are most often used for cognitive analysis, they can be useful for depicting hierarchical behavioral task relationships as well. An extensive list of such tools is given in Wikipedia articles at http://en.wikipedia.org/wiki/List_of_Mind_Mapping_software and http://en.wikipedia.org/wiki/List_of_concept_mapping_software.

SUMMARY AND CONCLUSIONS

Criticisms and Limitations of Behavioral Task Analysis

Despite its widespread use for a variety of functions, behavioral task analysis is not without its weaknesses and critics. Some of those weaknesses and criticisms are briefly addressed here.

A major challenge is defining the task and then determining the level of analysis required for a particular application. There is usually pressure on the analyst to finish the analysis as quickly as possible so that the rest of the instructional design process can proceed. In those cases, the analysts may begin the analysis without giving proper analytical consideration to the job or function or sub-function. That approach can lead to products that lack the depth and rigor that will be required later on in the instructional design process. The feeling might be, "We already know the top-level information like the job and function, so let's not waste time at those higher levels. Let's go right to the 'meat' of the analysis of the tasks." Such an approach is suboptimal and the analyst will not have the proper context to define tasks for the entire job. The main danger is that there will be a complete low-level analysis, and good training, for the wrong tasks and functions.

Another criticism of behavioral task analysis is its heavy reliance on the use of subject-matter experts. It is not often possible to do a complete task analysis based on observations and interviews in the field alone. In many cases, analysts must rely on subject-matter experts to give them a detailed understanding of what tasks must be performed and why. Subject-matter experts can be an excellent source of task information, but it may be difficult to obtain the required number of subject-matter experts because they are usually in high demand performing the job. In an effort to achieve reliability of information, analysts usually should interview at least three to five subject-matter experts. In addition, there is a criticism that the information obtained from subject-matter experts may be somewhat biased because they have learned "shortcuts" through the years in doing the tasks that require extraordinary knowledge or ability. In those cases, it would not be appropriate to teach the shortcuts to inexperienced trainees because they do not have that extra knowledge or skill yet. Another problem is that purported subject-matter experts may not really be expert; while sufficiently experienced, they may have little in-depth technical understanding of the specific task. Finally, a practical difficulty in working with some subject-matter experts is whether they are able to articulate what is required to perform a task. They may be experts in their field, but that does not necessarily mean they have the communication skills necessary to explain what tasks must be performed, or when, or how, or why. Alternatively, they may be quite inexpert, but have good persuasion skills.

Are these criticisms of behavioral task analysis discussed above justified? Although there is merit to these critiques, these problems are relatively minor when compared to the benefit that behavioral task analysis brings to the performance improvement process. The problems cited with using subject-matter experts can be largely mitigated as long as the analyst anticipates the difficulties. For example, the analyst can explain to managers and colleagues on the performance improvement team that the analysis should not be rushed or curtailed simply to meet a timeline. Another consideration is that an analyst might ask for twice as many subject-matter experts as really needed just to make sure they have the desired number of experts. The analyst can continually remind the subject-matter experts that they need to stick to the formal method for performing the tasks and not implement shortcuts because novices will be the primary users of the resulting instruction or job performance aid.

Future of Behavioral Task Analysis

As long as jobs change, new systems are developed, or there is a desire to improve job performance, there will be a continuing need for quality behavioral task analysis. And, as such, task analysis is a dynamic rather than static field that continues to evolve in response to both the demands of the workplace and the increasing understanding of human performance.

Currently, behavioral task analysis provides the tools necessary to characterize well-defined procedural work. It will become easier to perform such analysis in the future as information technology automates the routine, mechanical aspects of documenting tasks and describing their relationships.

The challenge for future task analytic methods will be the continuing development of hybrid procedures that include both behavioral and cognitive components. The need to link behavior and cognition in order to provide a unified description of the work that people perform is critical as we continue to move from routine procedural work to work that is performed within increasingly complex socio-technological systems. These systems involve numerous individuals, teams, and technologies that respond dynamically to their changing environment. As a result, human performance professionals need to develop greater understanding of how the relationship between behavioral, cognitive, social, and technological factors shapes the behavioral demands for the next generation of work.

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APPENDIX A: U.S. GOVERNMENT DOCUMENTS DETAILING PROCEDURES FOR BEHAVIORAL TASK ANALYSIS

As an instructional systems development benchmark, the 1975 Interservice Training Review Organization (ITRO) Instructional Systems Development methodology (Branson, Rayner, Cox, Furman, King, & Hannum, 1975) (described in the rescinded NAVEDTRA-106A and TRADOC Pamphlet 350-30) provided the initial framework for the Joint Service process model. The interservice procedures were amended around 1980 (e.g., NAVEDTRA 110A), and later were replaced in the mid-1980s with a Military Standard for Instructional Systems Development (MIL STD 1379D) supported by MIL HDBK 1379 (four volumes) and MIL HDBK 292 (two volumes), which itself was replaced in the 1990s with a "Performance Specification for Training Data Products" (MIL PRF 29612), supported by a new Department of Defense Handbook for Instructional Systems Development/Systems Approach to Training and Education (MIL-HDBK-29612-2A). (This is Volume 2 of a five-volume series on military training.) The others are MIL-HDBK-29612-1, Department of Defense Handbook, Guidance for Acquisition of Training Data Products and Services, which contains guidance to be used by all services for the preparation of solicitations and evaluation of solicitation responses for training. MIL-HDBK-29612-3, Department of Defense Handbook, Development of Interactive Multimedia Instruction (IMI), which contains guidance on the application of the multimedia training courseware development process. MIL-HDBK- 29612-4, Department of Defense Handbook, Glossary for Training, which contains a listing of training terms and definitions. MIL-HDBK-29612-5, Department of Defense Handbook, Advanced Distributed Learning (ADL) Products and Systems describes methods and procedures for developing distance- and distributed-learning services and curricula.

The current Military Handbook MIL-HDBK-29612-2A contains an extended discussion of behavioral task analysis methods.

Each of the United States Armed Forces and the Department of Defense has its own amplifying information and guidance. These are listed in Table 6.7.

Table 6.7 Department of Defense Guidelines

Department of Defense	
DoDISS	Department of Defense Index of Specifications and Standards
DI-SESS-81518B	Instructional Performance Requirements Document
CJCSM 3500.04	Universal Joint Task List
Department of the Army	
TRADOC Regulation 350-70	Training Development Management, Processes, and Products
TRADOC PAM 350-70-1	A Guide for Producing Collective Training Products
TRADOC PAM 350-70-2	Multimedia Courseware Development Guide
Department of the Navy	
NAVEDTRA 130	Task Based Curriculum Development Manual
NAVEDTRA 131	Personnel Performance Profile Based Curriculum Development Manual
NAVEDTRA 134	Navy Instructor Manual
NAVEDTRA 135	Navy School Management Manual
United States Marine Corps	Systems Approach to Training Manual
Department of the Air Force	
AFPD 33-22	Military Training
AFMAN 36-2234	Instructional Systems Development
AFH 36-2235	Information for Designers of Instructional Systems (in twelve volumes) Volume 1–Executive Summary Volume 2–ISD/SAT Automated Tools/What Works Volume 3–Application to Acquisition

(*Continued*)

Table 6.7 (*Continued*)

Department of the Air Force	
	Volume 4–Manager's Guide to New Education and Training Technologies Volume 5–Interactive Courseware (ICW) Design, Development and Management Guide Volume 6–Guide to Needs Assessment Volume 7–Design Guide for Device-Based Aircrew Training Volume 8–Application to Aircrew Training Volume 9–Application to Technical Training Volume 10–Application to Education Volume 11–Application to Unit Training Volume 12–Information for Designers of Instructional Systems
Coast Guard	
Coast Guard Commandant Instruction (COMDTINST) 1550.9	Management of the Coast Guard's Training System
COMDTINST M1414.8C	Enlisted Performance Qualifications Manual
Other Government Agencies	
Department of Energy	10 CFR 712 Human Reliability Program 10 CFR 1046 Physical Protection of Security Interests
Federal Railroad Administration, Department of Transportation	49 CFR 236 Rules, Standards, and Instructions Governing the Installation, Inspection, Maintenance, and Repair of Signal and Train Control Systems, Devices, and Appliances